DESIGN OF A COOLING EJECTOR UNDER THERMAL ANALYTICAL CONDITIONS FOR FINDING ITS PERFORMANCE

VADLAKONDA SANTHOSH
M. Tech Student, Dept of Mechanical-THERMAL, Brilliant grammar school educational institutions group of institutions integrated campus, T.S, India

G. NACHIKET G C
Assistant Professor, Dept of Mechanical-THERMAL, Brilliant grammar school educational institutions group of institutions integrated campus, T.S, India

ABSTRACT:

The aim of this study is to investigate the use of CFD in predicting performance of a steam ejector used in refrigeration applications. The CFD results were validated with the experimental values. The effects of operating conditions and geometries on its performance were investigated. The CFD's results were found to agree well with actual values obtained from the experimental steam jet refrigerator. The CFD was found to be not only a sufficient tool in predicting ejector performance it also provide a better understanding in the flow and mixing processes within the ejector. The hybrid of the simple and reliable ejector system and the technologically mature vapour compression system can be very beneficial. When solar energy or the cost-effective waste heat can be introduced as the ejector's heat source, the combined system can also realistically achieve a COP improvement of around 20–50%.

***Keywords**: Ejector, Jet refrigeration, Jet pump CFD*

1.0 EJECTOR INTRODUCTION:

Ejectors are a simple type of jet-pump that are often used for vacuum generation or for vapour compression. They provide an alternative to conventional mechanical vapour compressors in that they can be primarily powered by relatively low grade thermal energy instead of by electricity. Ejectors have been used in different applications two-phase ejectors were used in a condensing configuration .Also noted is that the first vapour-jet ejector applications In Parsons and Leblanc's applications, vapour-jet ejectors used steam as both the driving and suction fluids in the ejectors. The use of vapour-jet ejectors operating with steam continues today, however the applications are limited to evaporator temperatures above zero degrees Celsius. One of the principle advantages of operating ejector-based cooling systems is their ability to operate using relatively low grade thermal energy. Sources of low grade thermal energy, typically at temperatures below 120 oC, are found in the reject streams from many different industrial applications such as in the rejected steam and exhaust gasses from boilers, turbines and engines, as well as from renewable sources such as solar energy or geothermal wells. As much of the world's electricity is generated from fossil-fuels, any reduction in electricity consumption will result in a reduction in the emission of carbon dioxide and other combustion by-products from the energy conversion processes. An additional benefit of ejector-based cooling systems is that the ejector has no moving parts, thus requiring very little maintenance and providing highly reliable cooling over very long periods of time. With advances in refrigerants over the past fifty years, it has become feasible to operate vapour-jet ejectors with fluids other than steam. The use of refrigerants other than water provides two principal benefits; the potential elimination of the zero degree Celsius limit on evaporators, and a possible improvement of the performance of a vapour-jet ejector cooling system. Some notable studies of vapour-jet ejectors operating with steam include the works of some studies focused on the use of synthetic or natural refrigerants in ejector-based cooling systems are described.

COOLING EJECTOR CYCLE:

In the simplest form of the vapour-jet ejector refrigeration cycle, the compressor of a standard refrigeration cycle is replaced by a pump, a vapour generator and the ejector. Instead of driving the compressor with electrical energy, the ejector is driven by vapour from the vapour generator, vapour provided by harnessing low-grade thermal energy. As seen in Fig. the simplest vapour-jet ejector cycle consists of two loops that interact in the ejector. In the primary loop, liquid from the condenser is pumped into the generator where it is boiled using an external heat source. The resulting high-pressure, high-temperature vapour then flows through a converging-diverging nozzle where its energy is converted to kinetic energy in the form of a supersonic velocity flow of gas. The secondary stream is entrained into the ejector by both the low pressure generated by the expansion of the primary stream and the momentum transfer from the primary stream to the secondary stream along the surface of contact between these two. The two streams mix and the resulting flow exits the ejector through a diffuser.

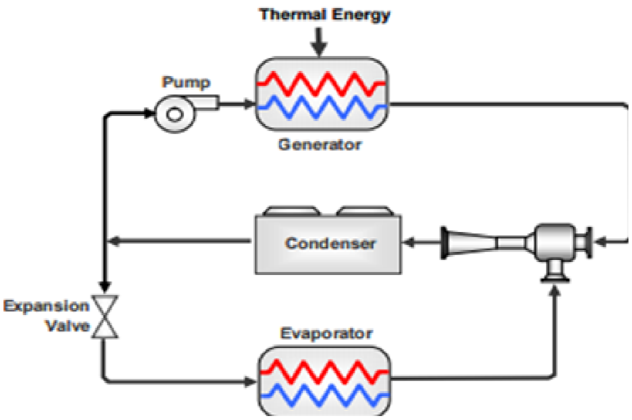


Figure 1. Schematic illustration of the simplest cooling ejector cycle

ELEMENT EJECTOR SYSTEM

Whether for lube oil, fuel oil, or general fractionation, vacuum columns utilize ejector systems to maintain design vacuum levels within the column. Noncondensable, cracked gases, hydrocarbon vapours and steam are removed from the column by the ejector system. Extraction of these fluids from the column is key to a proper vacuum level within the column and consequently, design charge rates and specification quality product are achieved. Refiners do have lengthy operating experience with ejector systems. Ejector systems have been the mainstay for refinery vacuum distillation. Whether a crude vacuum tower operates as a 'wet', 'damp' or 'dry' tower, an ejector system is the vacuum producer. Different tower operating pressures and overhead load characteristics of wet, damp or dry operation affect only the configuration of an ejector system but the basic operating principle remains unchanged. Even with lengthy operating experience, refiners view ejector systems with hesitation and uncertainty. This uncertainty results from an incomplete understanding of the basic operating principles of ejectors themselves and their interdependency with any vacuum condenser it supports or to which it discharges.

[1] T. Aravind1 , Dr P Ravinder Reddy 2 , S SBaserkoed (2014)" This work focuses on the numerical simulation of the working of a steam ejector in order improve the performance. Computational Fluid Dynamics (CFD) was employed for the numerical simulation. In this work the effect of operating conditions on the performance of the steam ejector operating in conjunction with an ejector refrigeration cycle was considered along with the effect of geometry parameter. The model and meshing is done with GAMBIT and FLUENT solver is used for the analysis. The simulations are performed with different operating conditions and geometries. The Entrainment ratio (ER) is found to increase with the decrease of boiler saturation temperature for the same condition of superheat, evaporator temperature and condenser pressure. The entrainment ratio is also found to increase with increase of evaporator temperature.

[2] Arth R. Patel ,Mr.Jayesh (2015) Jet ejectors are popular in the chemical process industries because of their simplicity and high reliability. They are widely used to generate vacuums with capacity ranges from very small to enormous. Due to their simplicity, constant-pressure jet ejectors that are properly designed for a given situation are very forgiving of errors in estimated quantities and of operational upsets. Additionally, they are easily changed to give the exact results required. The results obtained through the analysis show that despite reducing the steam inlet pressure, the outlet pressure condition remains the same, as such the efficiency of the refrigeration plant is improved since less energy is required to generate motive steam pressure and temperature.

[3] Dr. I. Satyanarayana (2016) Ejectors are widely used in many applications such as water desalination, steam turbine, refrigeration systems, and chemical plants. This project work carries the numerical simulation of the working of a steam ejector in order improve the performance. Computational Fluid Dynamics (CFD) was employed for the numerical simulation. The Entrainment ratio (ER) is found to increase with the decrease of boiler saturation temperature for the same condition of superheat, evaporator temperature and condenser pressure The entrainment ratio is also found to increase with increase of evaporator temperature The entrainment ratio does not vary much with the condenser pressure until the critical condenser pressure.

[4] Jaime Honra, Menandro S. Berana, Louis Angelo M. Danao "(2017) Ejector for refrigeration application is increasingly becoming very attractive due to its simplicity and significant reduction in overall cost. However, most of the studies are still limited to one-dimensional mathematical modelling and physical experimentation. Data acquisition from physical investigations requires extensive

effort and considerable time and is very expensive; whereas, Computational Fluid Dynamics (CFD) could be a more efficient diagnostic tool for ejector design analysis and performance optimization than one-dimensional mathematical modelling prior to actual experimentation. A near optimal ejector operation is characterized by a number of oblique shocks that gradually fades into a weak shock at the end of the mixing section for an effective recompression. Overexpansion and under-expansion of the jet coming from the nozzle indicate ineffective recompression and lower entrainments, respective.

3.0 METHODOLAGY:

Computational fluid dynamics modeling was developed to predict the characteristics and performance of flow systems. Overall performance is predicted by breaking the flow system down into an appropriate number of finite volumes or areas, referred to as cells, and solving expressions representing the continuity, momentum, and energy equations for each cell. The process of breaking down the system domain into finite volumes or areas is known as mesh generation. The number of cells in a mesh varies depending on the level of accuracy required, the complexity of the system, and the models used.

ASSUMPTIONS IN CFD:

The physics of conjugate heat transfer in radiator is simplified with the following technically valid assumptions.

- Velocity and temperature at the entrance of the radiator core for air and coolant is uniform.

- No phase change occurs in fluid streams.

- Fluid flow rate is uniformly distributed through the core in each pass on each fluid side. No flow leakages occur in any stream. The flow condition is characterized by the bulk speed at any cross section.

- The thermal conductivity of the solid material is constant.

EJECTOR WORKING PRINCIPLE:

As outlined in a typical ejector consists of a motive nozzle, a suction chamber, a mixing section and a diffuser. The working principle of the ejector is of converting internal energy and pressure related flow work contained in the motive fluid stream into kinetic energy. The motive nozzle is a converging-diverging design

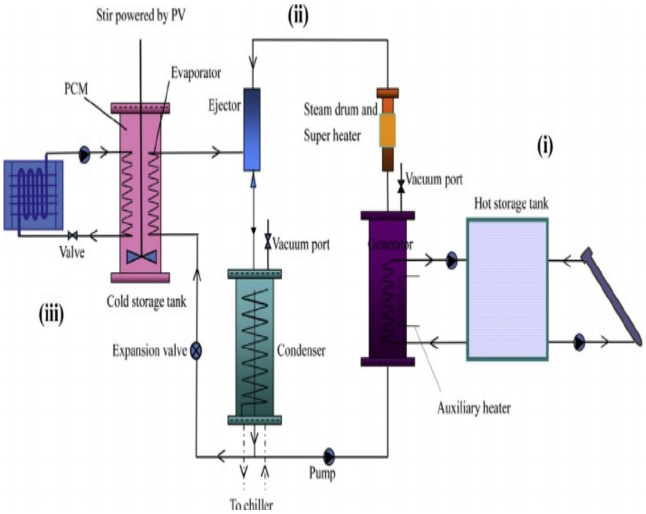


Figure cooling ejector

Depending on the state of the primary fluid, the flow at the motive nozzle exit might be 2-phase. Flashing of the primary flow inside the ejector might be delayed due to thermodynamic and hydrodynamic non-equilibrium effects. The high-speed jet initiates the interaction with the secondary fluid which is inside the suction chamber. Momentum is transferred from the primary flow to the secondary flow.

The properties of fluid and aluminium

Property	Fluid	Aluminium
Density, kg/m3	1.225	2719
Specific Heat(Cp), j/kg-k	1006.43	871
Thermal Conductivity, w/m-k	0.0242	180
Viscosity, kg/m-s	1.7894e-05	-
Molecular Weight, kg/kgmol	28.966	-

Ejector geometry:

The dimension of the ejector which is used for the analysis is considered from and the three different primary nozzle dimensions detailed dimensions of steam ejector is used to build the geometry in Gambit software. The other important dimensions for creating the geometry were assumed:

Suction inlet diameter = 49.2mm,

Ejector outlet diameter = 40mm,

Length of straight cross section after the diffuser = 20mm.

Distance of Nozzle from Mixing Section = 5 mm

Three 2-D Axial Symmetrical model was created according to the three primary nozzle dimension specified The model is then meshed to the wall was refined using boundary layer meshing is given in Fig.

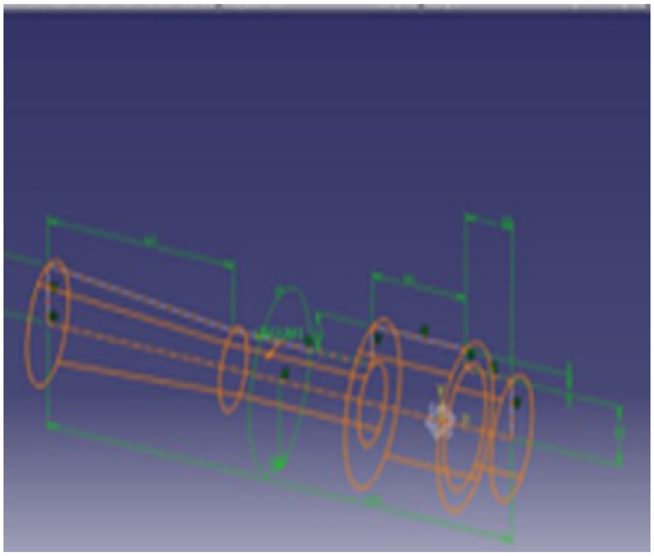


Figure Geometry model of cooling ejector

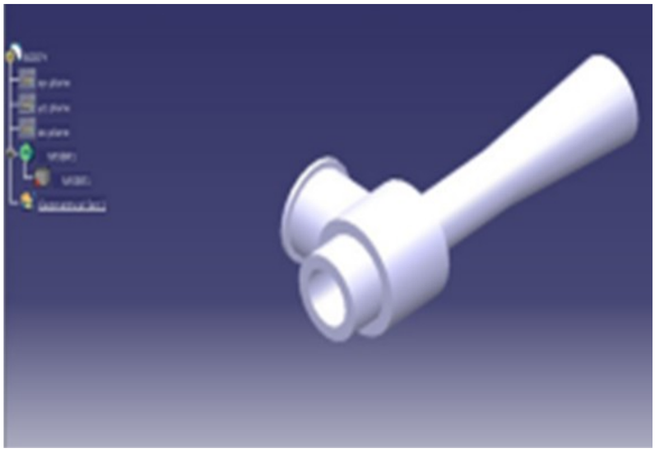


Figure isometric view of cooling ejector

Meshing:

The Figure shown is the meshed model of rigid flange coupling in the ANSYS analysis for the static structural process. To analyse, the FEM triangular type of mesh is used for the rigid flange coupling in the ANSYS environment. The number of elements used in this meshing is 71441and the number of nodes is 122228.In this process regular type of meshing is done to analyse the process

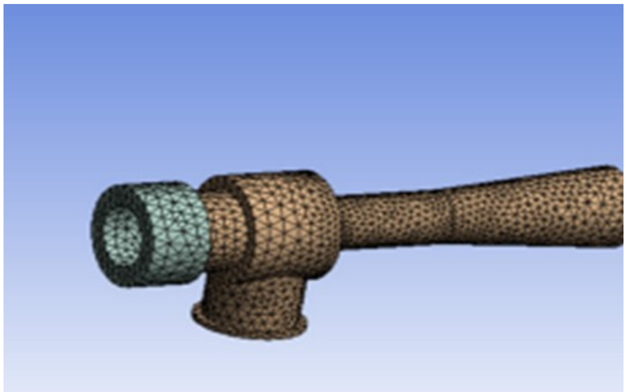


Figure Meshed model

Boundary Conditions

In this CFD analysis, the fixed ejector geometry used is intended for an ejector refrigeration system for air-cooled air-conditioning applications for specific on-design operating conditions suitable for tropical countries like the Philippines, as follows: The boundary conditions used for this analysis are at the primary inlet the boiler temperature is 1200C at 169.18 kPa, at the secondary inlet the three different cases of evaporator temperature are considered 50C, 100C and 150C respectively at 800 Pa, 1200 Pa and 1700 Pa and at the Ejector outlet the condenser pressure of 25 mbar.

4.0 RESULTS AND DISCUSSIONS:

The numerical analysis was designed to investigate the changing of the static pressure through the ejector axis when the parameters affecting the ejector performance were varied. The operating conditions which are considered for the analysis. Steam ejector geometry model is created and meshed. The three different geometries are analysed at the same inlet and outlet conditions. The analysed results provide a better understanding in the working characteristics of a steam ejector. This section gives the conformity of results obtained with the experimental results.

CFD ANALYSIS ON EJECTOR ORIGINAL MODEL (Working fluid R134a) IMPORT CATIA MODEL.

- Open Ansys Workbench and then Fluid Flow (Fluent) → double click
- Select geometry and then right click,
- Import geometry by choosing the → select browse →open part → ok

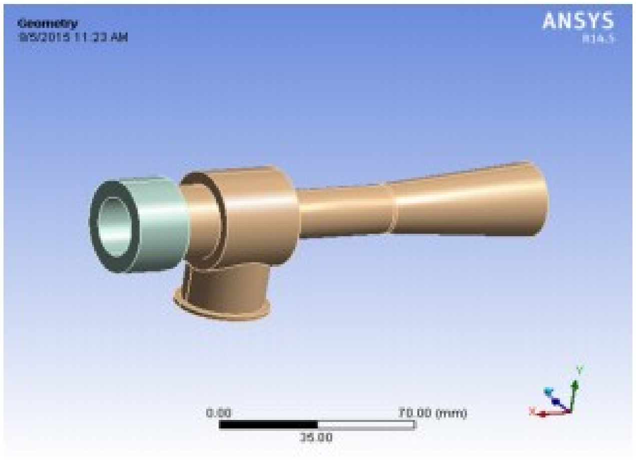


Figure Geometric model

Static Pressure Contours Of The cooling Ejector: For Different Cases The Static pressure contour corresponding to the boiler temperatures 120o C,130o C and 140 o C.

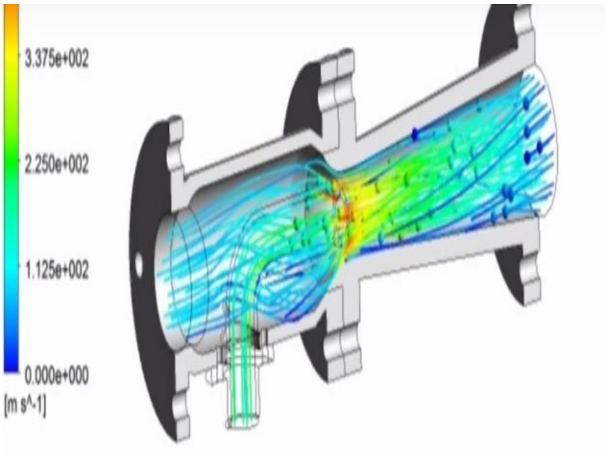


Figure vector steam line 1

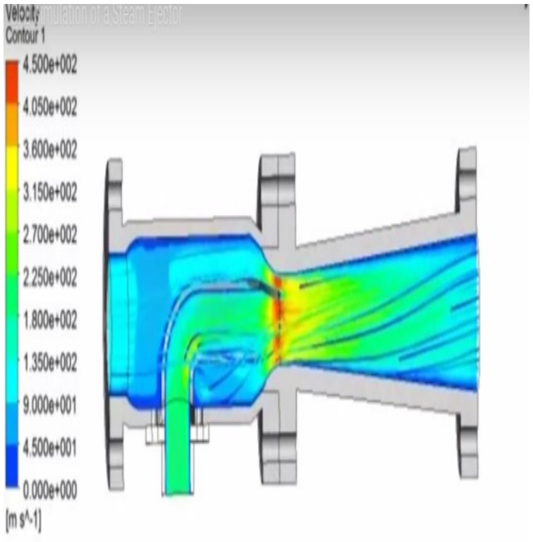


Fig Velocity counter1

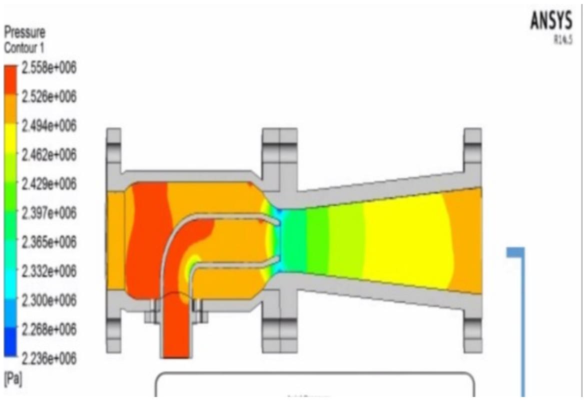


Fig pressure counter1minimum deformation

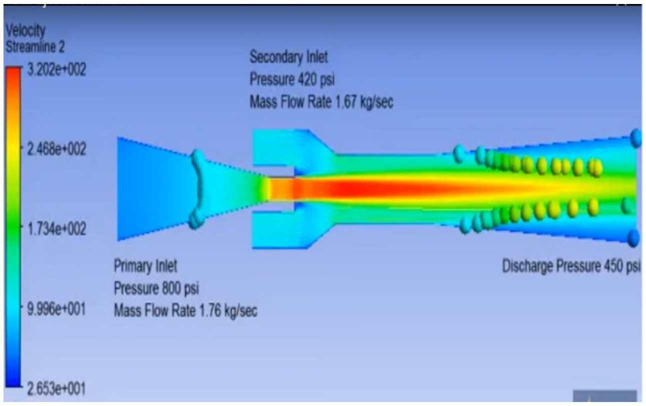


Fig velocity steam line 2

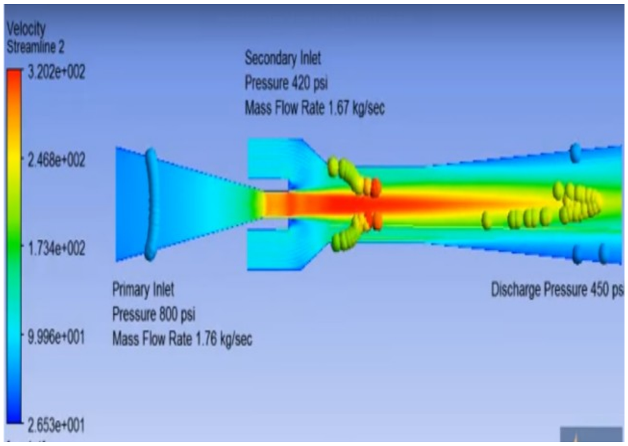


fig Secondary inlet pressure

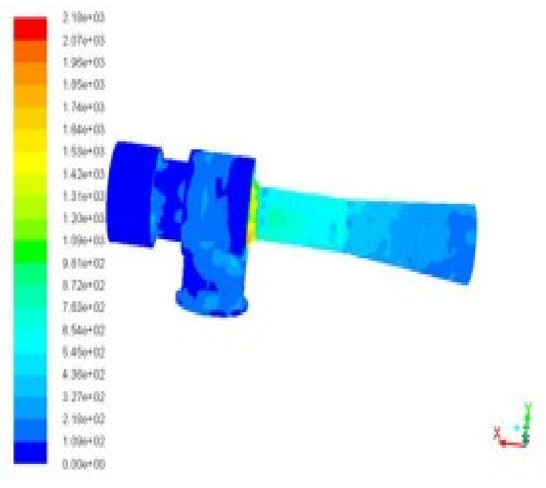


Figure explaining wall shear stress

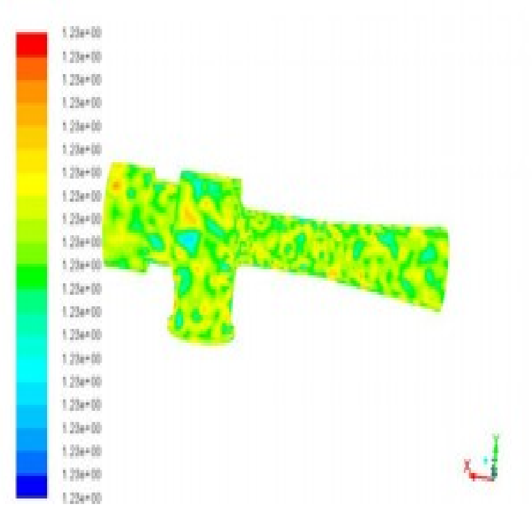
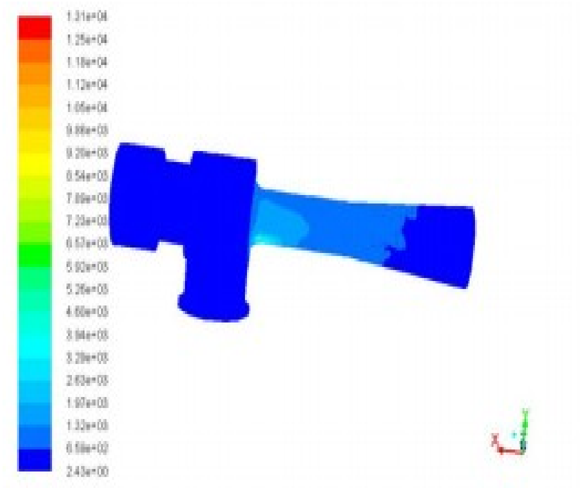
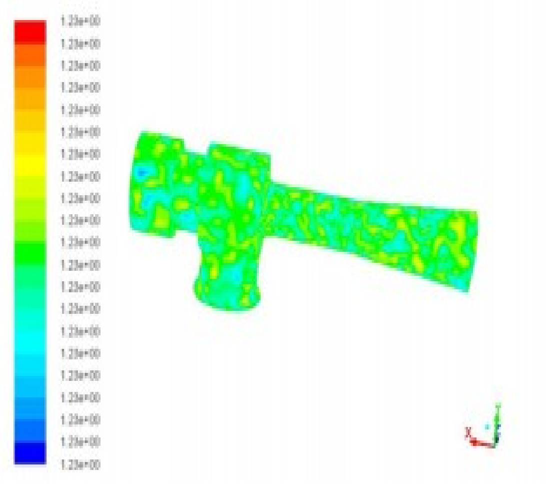


Figure explaining density



Figexplaining turbulent kinetic energy

CFD ANALYSIS ON EJECTOR MODIFIED 1(Working fluid R134a)



FigMass Flow Rate Results

CFD ANALYSIS ON EJECTOR MODIFIED 2 (Working fluid R134a)

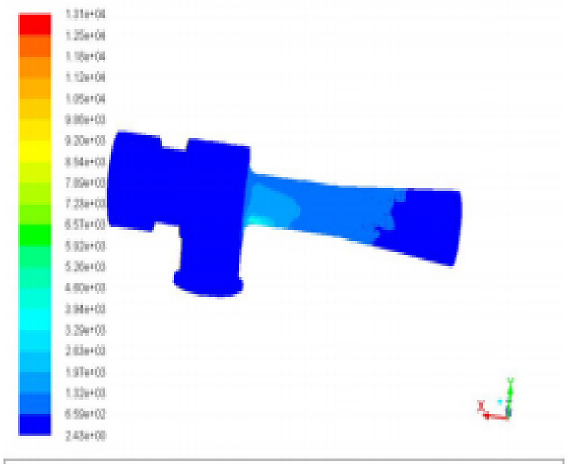
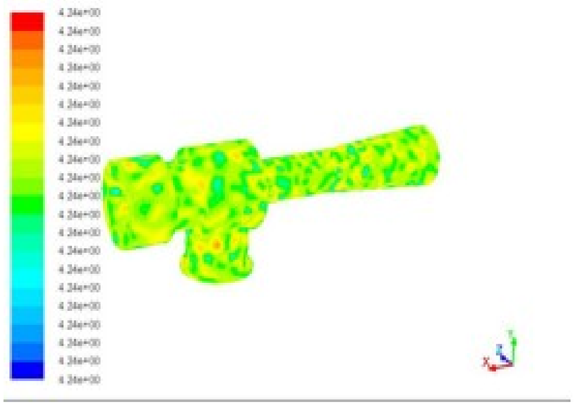


Figure explaining turbulent kinetic energy



Figexplaining density

TABLE 4.1 CFD ANALYSIS OF EJECTOR RESULTS TABLE

	VELOCITY MAGNITUDE	STATIC PRESSURE		
		max	min	
original	6.72E+02	-2.77E+05	2.07E+05 3	3.00E+02
Modified 1	1.76E+01	-1.92E+02	1.03E+02	3.00E+02
Modified 2	1.74E+02	-2.93E+03	1.01E+03	3.00E+02

TABLE 4.2 CFD ANALYSES OF EJECTOR RESULTS

	SHEAR STRESS	KINETIC ENERGY		DENSITY	MASS FLOW RATE
		max	min		
original	2.18E+03	2.43E+00 1	1.31E+04	1.23E+00	6.24E-06
Modified 1	4.96E+00	1.00E-03	1.71E+01	1.23E+00	1.86E-06
Modified 2	**0**	2.43E+00	1.31E+04	4.24E+00 0.9	0.925E-03

VALIDATION:

This section gives the conformity of results obtained with the experimental results Several publications were referred to and the results given in them were taken as benchmark results for validation Intensive investigations were carried out using the range of turbulence models available in a commercial CFD code, FLUENT which solves the governing conservation equations of fluid flow by finite volume formulation It is well known that all the turbulence models currently available have their own credibility and limitations Although, very advanced models are available to close the system of equations, no model can be used for the flow prediction in all sorts of flow systems The validation fundamentally means demonstration of computational fidelity bycomparing computational results to experimental data The methodology adopted for the present investigation involves comparing the predicted performance parameters and the distribution of flow parameters with the experimental results

CONCLUSION

In this paper we have designed a ejector with geometrical parameter it is different throat radius, at the nozzle will be considered. And the analysis in computational fluid dynamics (CFD) simulations of a vapour-jet ejector operating with R134a as the working fluid will be analysed. The impact of varying geometrical parameter such as throat radius on ejector performance is considered. As we compare the results obtained for the 3 types of analysis graphs and tables we can observe that the stress is very less an even negligible for the 2nd modified model, mass flow rates increase in the 2nd modified model and even if we see the remaining results we can conclude that the ejector with the diameter of throat inlet 3mm is a better product with best material by using R134a.Ejector systems support vacuum tower operation. Proper operation of an ejector system is important; without it, the vacuum tower performance is not optimal. When tower pressure increases above design operating pressure, flash zone pressure increases proportionally. The consequence of higher flash zone pressure is reduced vacuum gas oil yields and increased vacuum reside. When charge rates to the tower are less than design, the ejector system will pull the tower to a lower pressure. Lower pressure in the tower may adversely affect tower hydraulics and cause flooding. This will affect vacuum gas oil quality. With annual performance evaluations of ejector systems, improved product quality, increased unit throughput or reductions in operating costs can often be realized.

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